PATENT SPECIFICATION

(11) 1 548 997

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(21) Application No. 11128/76 (22) Filed 19 March 1976

(31) Convention Application No. 560290

(32) Filed 20 March 1975 in

(33) United States of America (US)

(44) Complete Specification published 25 July 1979

(51) INT CL² H01J 61/16 A61N 5/06 H01J 61/90//H05B 41/34

(52) Index at acceptance

H1D 12B47Y 12B4 12C 18L1 18L4 18LY 35 5A 5C3 5H 5P3 5Q 9A 9C1X 9C1Y 9C2 9CY 9D 9FX 9FY 9G 9Y

F4R 202 203 232 23Y 262 269 275 27X 27Y 31X 32X 339 407 40Y 433 466 547 705

H2H 23G 25G 25Y B8 LD1

(19)

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(54) RAPID PULSE ULTRAVIOLET LIGHT APPARATUS

(71) We, DENTSPLY INTERNATIONAL INC., a company organised under the laws of the United States of America, of 500 West College Avenue, York, Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a lamp for delivering light energy in the ultraviolet range.

In the fields of medicine and dentistry there have been recent developments which have increased the interest in and use of ultraviolet light energy both as a treatment agent and for its ability to be used to activate polymerization of certain kinds of polymeric compositions, for example to produce splints, dental sealants, dental filling materials and dental adhesives for orthodontic appliances. In particular, in the protection of the teeth of human beings, and especially children, an important development in decreasing the incidence of cavities involves applying a liquid resin which penetrates crevices in the occlusal or biting surfaces of teeth, and which can be polymerized to form a tough adherent coating. Ultraviolet radiation has been used extensively as one mechanism for activating that resin polymerization. Other applications for ultraviolet activation of resin polymerization are for tooth filling materials for tooth restoration, cements for orthodontic attachments and polymerization techniques for crown and bridge prosthesis.

Ultraviolet lamps currently available for providing ultraviolet light radiation for the activation and curing of polymerizable liquid coatings or sealants have generally been most suitable for techniques not requiring great penetration of the polymerizable mass of material. To be suitable for such applications an ultraviolet light would have to be sufficiently rich in those wave lengths which are most efficient for curing the polymer in question. Otherwise, it would have to be hand-held for too long a period of time thereby inducing both patient and operator discomfort. Furthermore, known ultraviolet light devices might be prone to heat up to an uncomfortable extent if required to be used for a period sufficient to cure material to a considerable depth.

The basic cause for any excessive heating which might occur in known devices derives from the fact that they are inefficient in producing emissions at the desired ultraviolet wave lengths for the polymerization of the materials being used, i.e. approximately between 320 nanometers and 400 nanometers. In addition, the devices currently in use require a long warm-up time thereby tending to reach a high threshold temperature while not in use. This tends to diminish their useful working life. Additionally, known devices have been characterized by undesirably high total ultraviolet light output flux.

It is an object of this invention to provide an ultraviolet light source which is more efficient in the desired wave length range of ultraviolet emissions than prior art devices, for example for the polymerization of tooth restorative and sealant materials so as to cause rapid curing of such materials with a lower total power output.

In accordance with the present invention there is provided an unconfined arc lamp filled with substantially only xenon, comprising main arc electrodes having spaced therebetween trigger electrodes for initiating and positioning a pulsed arc between said main arc electrodes, said electrodes being contained within a lamp envelope so that the pulsed arc forms freely between the electrodes without being confined by the walls of the said envelope, wherein at least a portion of said envelope is transparent to the ultraviolet radiation produced by the pulsed arc in the

range of from 320 to 400 nanometers and the lamp envelope is filled with xenon at a pressure in the range of from in excess of 3 atmospheres up to 10 atmospheres, and wherein means are provided for delivering to the trigger electrodes trigger pulses at a pulse repetition rate of from 20 to 400 pulses per second.

The invention may be embodied in a lightweight structure suitable for hand-held operation, and having an unconfined arc xenon light source in operative association with light delivery means for delivering ultraviolet radiation to a restricted location, the device also having circuitry for pulsing the light source at preselected voltages and current so as to produce a rich source of near ultraviolet light irradiance which is a function of the average power delivered to the unconfined arc xenon light to source. In this embodiment suitable power supplies and a pulse generator are provided in a housing which is appropriately heat sinked and is connected to the light producing source device through a coaxial transmission line to reduce to a minimum line inductance, the generated trigger pulses, so called, being connected to a trigger circuit at the light source so as to provide for delivery of a pre-selected number of light pulses per selected unit of time so as to maximize the average power output to correspond to wavelength emissions most desired for curing the polymerizable materials.

In the accompanying drawings:

Fig. 1 is a perspective view of a hand-held ultraviolet light source in combination with a power supply and pulse timing circuitry which is connected to the hand-held device through a connector;

Fig. 2 is a cross-sectional view of a portion of the hand-held light source, showing the relationship between the light source and the light pipe which delivers the ultraviolet radiation;

Fig. 3 is an exploded perspective view of a portion of the hand-held apparatus;

Fig. 4 is a circuit diagram of the electrical portion of a first embodiment of the light source apparatus of this invention;

Fig. 5 is a circuit diagram of a second embodiment of the light source apparatus of this invention; and

Fig. 6 is a schematic representation of a system using the light source apparatus of this invention and employing a light pipe between the ultraviolet source and the hand-held gun.

As shown in Fig. 1, a hand-held device 20, in the form of a gun, comprises a handle 22 and a light source housing 23. The handle 22 contains a suitably located button 26 which operates an electrical switch 82 shown in the schematic circuit of Fig. 4.

A cylindrical ultraviolet light generating tube 30 is contained within the inner cylindrical surface of housing 23, as seen in Fig. 1 and Fig. 2. The light generating tube 30 is an unconfined xenon arc flash tube, the xenon gas pressure being maintained at a high pressure, i.e., greater than 1 atmosphere. By "unconfined", it is meant that the xenon arc is not confined by a glass envelope, but rather is freely formed between the electrodes, such as the configuration of sub-atmospheric tubes manufactured by EG & G of Salem, Massachusetts. The typical lamp tube employs a number of trigger electrodes 33 (Fig. 2) for the purpose of initiating the main arc for each pulsed flash of light. The trigger electrodes help to stabilize the trigger arc and main xenon arcs with respect to position. The unconfined arc flash tube contains a pair of closely spaced electrodes 31, anode and cathode respectively, between which the main arcs form. An unconfined arc flash tube of this configuration permits an arc as small as 1/8 inch, which is an excellent arc plasma size for directing a high percentage of the total amount of light produced to a light rod 24 without requiring special reflectors and focusing devices. The envelope of the tube 30 is suitably made of a glass such as CORNING 0080, which cuts off unwanted light emissions at wavelengths below 320 nanometers.

Typically, the superatmospheric unconfined arc flash tube as disclosed in this invention has the following spectral efficiency:

Wavelength	% Emission
320 nm—500 nm	38.5%
500 nm—700 nm	26.9%
700 nm—900 nm	20.0%
900 nm—11,000 nm	14.6%
320 nm—11,000 nm	100%

By contrast, the typical subatmospheric confined arc flash tube has the following spectral efficiency:

Wavelength	Emission
320 nm—500 nm	11.3%
500 nm—700 nm	12.8%
700 nm—900 nm	13.1%
900 nm—1100 nm	14.7%
1100 nm—11,000 nm	48.1%
320 nm—11,000 nm	100%

From the above, it is seen that an unconfined arc tube produces an output which is shifted towards shorter wavelengths. Since the colour temperatures for the superatmospheric unconfined arc tube are shifted toward the shorter wavelengths, much less tube heating is experienced (the most efficient heating wavelengths being in the 900 nm—11,000 nm range). This low level of heating

is, of course, a very desirable feature for, for example, dental use of the device.

The xenon tube has a colour temperature in the region of 24,000°K and provides a substantial output continuum through the spectral range of 320 nm to 400 nm. This is in contrast to the typical prior art light source which, for example, concentrates a high percentage of its output energy in a peak at about 365 nm. It is important for the applications discussed above, that the light source should provide an output which is substantially continuous throughout the desired range, i.e., not have a high percentage of its output concentrated in one or several narrow peaks but have it spread out reasonably uniformly throughout the range. The tube used in this invention provides just such characteristic, which permits more rapid curing with a smaller energy output. For example, using the light source of this invention has enabled twice as efficient cure as a prior art device, and this increased efficiency is achieved with only about one quarter as much radiated energy, between 320 nm and 380 nm.

In tests, it has been demonstrated that as the xenon gas pressure in the tube is increased, the level of light output increases considerably for the same electrical energy input. For example, in using this tube for curing a sealant sample of a given thickness, a time period of 10 minutes at a flash repetition rate of 60 pulses per second was required when the xenon gas pressure was equal to atmospheric pressure. Increasing the xenon gas pressure to in excess of 3 atmospheres, while using the same repetition rate and pulse length, provided more rapid curing of the sample of same thickness. Other investigations have shown that with further increased pressures, additional increased ultraviolet light curing efficiency is obtained. In practice, a pressure of 4 atmospheres has been found to be best. The present invention uses a range of from in excess of 3 up to 10 atmospheres.

Still referring to Figs. 1 and 2, the light pipe 24 is mounted coaxially with the light housing member 23, and in operative relationship with the light generating tube 30, so that the main arc between the electrodes 31 is positioned right in front of the inner end surface 24S of the light pipe 24. In this way, there is efficient collection of the emitted ultraviolet light into the pipe 24. As seen in Fig. 3, the pipe 24 has a curved end, and may be provided with a focusing piece 25 for focusing the emitted light on to, for example, a tooth surface. A visible light filter 27 may be placed between the source 30 and the pipe 24. The pipe 24 is preferably a quartz rod having an aluminized or similar light reflective coating thereon. Such a coating, which may be applied to the outside of the rod by vacuum deposition, prevents light leakage at the bend or from the sides of the rod.

Most of the pulse generating circuitry is contained in the housing 39 which is connected through a coaxial transmission cable 40 to the gun 20. As explained in more detail in connection with Fig. 4, the circuitry in housing 39 provides the flash discharge energy to the lamp 30. Additionally, pulse signals are supplied through a transformer 38 and a tube pulse network (made up of capacitors 37 and resistors 36) to tube socket terminals 32. The generated trigger pulses have a fast rise time of less than about 2 microseconds, providing the starting arc that initiates the main discharge arc. Accordingly, it is desirable to have a low inductance and low resistance connection between a discharge capacitor 60 and the tube discharge electrodes 30A and 30C. This is provided by use of the coaxial cable 40. It has been found that the difference between the use of an ordinary double lead connection and the coaxial lead is substantial, the coaxial lead providing a much lower circuit inductance. When the rise time of the high frequency pulse is allowed to increase due to transmission inductance, the resulting ultraviolet light energy output from the tube, when pulsed, is decreased significantly. Tests have shown that the percentage of the energy discharge through the tube during a flash, which is converted to light is about three times as great when a coaxial line is used.

Referring now to Fig. 4, there is shown an embodiment of a circuit diagram of the electrical portion of this invention. The portion of the circuitry which is contained within the dashed blocks 20A is in fact housed within the gun 20. The remainder of the circuitry is contained in the housing 39. The housing, or external portion of gun 20, is electrically earthed, as shown by the connection from blocks 20A to earth.

Power is obtained through a socket 51 adapted for connection to a power line source, and fused through a conventional fuse 52. An on-off switch 53 provided on housing 39 connects the input power to a transformer 55 which provides about 1400 volts across the four-diode bridge 58, the rectified voltage being filtered by a capacitor 59. The rectified and filtered voltage charges the discharge capacitor 60 through a resistor 62. When the tube 30 is pulsed, discharge current from the capacitor 60 is transmitted through the coaxial cable to the gun 20, where it is connected across the anode and cathode of tube 30.

The tapped secondary winding 55A provides a 20 volt source and a 200 volt source. The 20 volt DC source is provided by a diode 68 connected to the winding tap, and a capacitor 69 and resistor 71 connected in parallel between the cathode of the diode 68 and

earth. This 20 volt supply is connected through a resistor 77 to terminal A of a unijunction transistor 78. Terminal C is connected through a ressitor 85 to earth. Terminal B of the transistor 78 is connected to the 20 volt supply through a resistor 81, and to earth through a capacitor 84. Terminal B is also connected through the on-off switch 82 (operated by the switch designated 26 in Fig. 1) through a resistor 83 to earth. When switch 82 is in the position shown as "on", unijunction transistor 78 and its associated circuitry comprise a pulse generator producing rapid rise pulses at the rate of about 60 pulses per second, the frequency being established by the values of the resistor 81 and the capacitor 84. It is to be understood that this pulse repetition rate need not be 60 pulses per second which is an illustrative figure.

The 200 volt source is derived from the transformer winding 55A through a half wave rectifier 67, and filtered by a capacitor 70 across which a discharge resistor 72 is connected to earth. This source supplies 200 volts through a charging resistor 75 to a capacitor 76 and the anode of an SCR 90. The output of the pulse generator is taken from terminal C to the gate of the SCR 90. The cathode of the SCR 90 is connected to earth. The SCR 90 is switched on and off 60 times per second, discharging the capacitor 76 into the primary winding of transformer 38. The pulses delivered at the secondary of the transformer 38 are of the order of 5000 volts, and are delivered through a trigger network comprising capacitors 37A, 37B and 37C in combination with resistors 36A, 36B, 36C, and 36D. As shown in Fig. 4, the trigger pulses are applied in parallel to trigger probes 2, 3 and 4 spaced between the anode 30A and cathode 30C of the tube 30. A small streamer arc is formed from 30C to 4, then to 3, then to 2 and on to 30A, such that the streamer arc is constructed between 30C and 30A. Capacitor 60 then discharges, forming the main light producing arc. Once the discharge is completed, the main arc turns off, the capacitor 60 re-charges, and the tube flashes again when the next trigger pulse arc is formed.

In practice, it has been found that the method of pulsing the unconfined arc high pressure tube, as disclosed herein, produces a high efficiency emission of near ultraviolet light energy for delivery to, for example, a tooth surface. By maintaining the tube at a superatmospheric or high pressure of at in excess of 3 atmospheres, there is no need to include afterfire inhibitors within the xenon flash tube, which inhibitors reduce ultraviolet light output. This aids in providing a high efficiency emission in the near ultraviolet wavelength range.

Referring now to Fig. 5, there is shown a modified form of a circuit arrangement for triggering and pulsing the ultraviolet light source. The second two digits of the reference numerals of this circuit are the same, where applicable, as the corresponding digits of similar components in Fig. 4. This circuit uses a constant voltage power transformer 155, preferably a ferro-resonant constant voltage transformer. The incorporation of such a transformer makes allowance automatically for power line voltage variations, which usually fall in a range of from about −30% to +15% of the nominal line voltage. A constant voltage transformer corrects within ±1% on the secondary side of the transformer. Such correction is highly desirable to enable the light source to operate efficiently at a lower power level, thus extending the life of the tube. The dashed block 120A indicates that portion of the circuitry and apparatus which is contained within the device 20.

The power input is obtained through plug 151, one line of which is earthed and one line of which is connected through fuse 152. A third line is connected through an on-off switch 154 to a switch 153. The switch 153 is used to set the apparatus for either 115 volt or 230 volt operation. The output of the switch 153 is connected to the input primary windings of the constant voltage transformer 155. The secondary of transformer 155 has various terminals for connection depending upon whether the local power source is 115 volt 60 Hz, or 230 volt 50 Hz. A main discharge capacitor 160 is charged from secondary terminal A (or A') through diode 158 every positive halfcycle of the power line. Resistors 161 and 162 form a voltage divider, and a connection is made between these resistors to the anode of an SCR 171 as well as to a capacitor 174, so that capacitor 174 is charged at the same time as the discharge capacitor is charged. The trigger circuit voltage is derived from terminal B of the secondary of transformer 155. Terminal B is connected through a resistor 175 to a diode 167 and a hybrid diode 168, which are also connected through a capacitor 169 to the gate of an SCR 171. The gate is connected through a low value resistor 170 to earth. A resonant capacitor 163 is connected between earth and either terminal C or C', depending upon whether the power source is 50 Hz or 60 Hz.

In this embodiment, a triaxial cable 140 is used. The discharge capacitor 160 is connected to two of the conductors of the cable 140, namely 140A and 140S. Two diodes 165 are connected in series across the discharge capacitor 160 which, in combination with high voltage surge diodes 197 and 198, ensures that proper polarity of the triggering sequence across the tube 130 is achieved. A damping network comprising a diode 175 in series with a resistor 176, and a resistor

177, which network is connected between the capacitor 174 and earth, serves to dampen the ringing effect caused by the inductance of transformer 138 at the time that a trigger pulse is transmitted. As is described hereinbelow, the trigger pulse is taken from the junction between the capacitor 174 and the diode 175, and connected to the centre conductor 140C of the triaxial cable the other end of which is connected to the primary of the transformer 138 which suitably has a 15:1 ratio.

At the UV tube 130, the output of the transformer 138 is connected across the tube anode 130A through a capacitor 184 and the tube cathode 130C. The transformer output is also connected through the capacitor network comprising capacitors 184, 185, 186 and 187 to the trigger electrodes F, G and H.

The following represent typical values and designations of components of the circuit of Fig. 5:

Diode 158	—2.5 Kv piv, 500 ma Avg.
Capacitor 160	2 μF
Resistor 161	—470 Kohm
	—2 μF
Resistor 162	—470 Kohm
Diodes 165	—IN 4725
Diode 167	—IN 914
Hybride Diode 168	—IN 5758
Capacitor 169	—0.022 μF
Resistor 170	—100 ohm
SCR 171	—RCA 52600M
Capacitor 174	—0.01 μF
Diode 175	—IN 4005
Resistor 176	—51 ohm
Resistor 177	—1 Kohm
Capacitors 184—187	—22 pF

In the operation of this circuit, trigger pulses are generated at the power line frequency. The main discharge capacitor is charged to a full charge during the positive half of the cycle and is triggered to discharge during the negative half of the cycle. This method of charging and discharging energy into the tube provides stable tube pulsing without the need for a charging resistor, thus providing good power supply efficiency and requiring fewer circuit components. During the positive half cycle when the main discharge capacitor 160 is charging, the trigger capacitor 174 is charging through resistor 161. During this time, the diode 167 conducts and prevents capacitor 169 from charging. During the negative half cycle of the power line, the capacitor 169 charges through the resistor 175. When it has charged to a value of about 20 volts, it discharges through diode 168 which conducts when such a back voltage is placed across it. This discharge generates a signal across the resistor 170 which gates on the SCR 171, which then provides a discharge path for the capacitor 174. The rapid discharge of the capacitor 174 produces a trigger pulse which is transmitted through the triaxial cable conductor 140C and the transformer 138 to trigger the tube 130. As stated previously, the damping circuit dampens any ringing effect caused by the inductance of transformer 138, so that only a single trigger pulse is transmitted through to the tube. The trigger pulse causes formation of a trigger arc in the tube, following which the energy stored in the main discharge capacitor 160 is discharged in the main arc through the tube.

The tube 130, as used in the embodiment of Fig. 5, comprises a tube envelope which is opaque to the emissions of the discharge. The tube envelope is preferably nonoxidizing, and is suitably of stainless steel. The tube has a small (15 mm diameter) glass window 131 through which the ultraviolet light is transmitted. This window is made of a glass which cuts off wavelengths below 320 nm. Additionally, for extra security against unwanted radiation, one or more sharp cut off light filters 128 may be positioned adjacent the window 131, the filters being suitably cemented to visible light filter 127. The filter or filters 128 may, for example, cut off wavelengths less than 320 nm, less than 325 nm, less than 330 nm, etc., as desired. Also, a reflector 195, or a plurality of such reflectors, may be positioned inside the tube and opposite from window 131, to optimize transmission of the ultraviolet radiation out of the window and into the light pipe.

Testing with the apparatus of this invention has led to the conclusion that the visible light filter 127 is highly desirable. The intensity of the visible light which is otherwise transmitted through to the tube surface and reflected therefrom can cause considerable operator eye fatigue. It is to be noted that the glass in the window 131 cuts off the harmful shorter wavelengths, while the visible light filter serves the function of eliminating visible light which would otherwise cause operator eye fatigue. The visible light filter must, of course, have a bandpass characteristic at the desired UV wavelength, between 320 and 400 nanometers. The commercially available glass filter 127 which has been used with this apparatus reduces the visible light to about 5%, while introducing approximately only 8% loss at the desired UV wavelength. By maintaining about 5% of the visible light, there is sufficient projection on to the tooth surface, when the apparatus is used in dentistry, to aid the user in aiming the gun output.

The two embodiments which have been described hereinabove provide a UV source which is particularly suitable for dental

application, with greatly improved safety features. The quartz rod 24 (or 124) is an excellent electrical insulator and is mounted into a handpiece which is earthed back to chassis earth. Through the use of the quartz rod any high voltage is kept from entering the oral cavity of the patient. Further, by using an optical window 131 of CORNING 0800 glass, which absorbs the short ultraviolet wavelengths below the desired wavelength range, an additional substantial safety increase is achieved. The design is fail safe, in that if the window cracks, the gas escapes and the tube becomes inoperative. By contrast, in apparatus which depends solely upon an external filter, if the filter cracks harmful radiation is emitted, and there is no way to discern the dangerous condition of the apparatus. A thermo-switch 180 protects the handpiece configuration from exceeding a predetermined temperature, acting to shut off automatically until it cools down to a given lower temperature.

The optical window 131 is preferably fused to the inside of the metal envelope opening, which construction further prevents short wavelength ultraviolet leakage. This arrangement has been used to produce a reliable UV source which operates at an average power of 70 watts to derive the level of UV output required for curing restorative and sealant materials within a time period of approximately one-half the cure time of known systems. The apparatus requires almost no warm-up time, needing only about 1.0 ms for full light output when the power line switch and trigger switch are turned on at the same time.

Referring now to Fig. 6, there is shown a diagrammatic view of another embodiment of this invention. In this embodiment, the power supply and all of the electronic circuitry are housed in an external housing 201, along with the ultraviolet source, i.e., the tube and associated trigger circuit components. Thus, the ultraviolet light pulses are generated externally to a hand-held device 205 which delivers the curing ultraviolet light pulses to the tooth surface. Connected between the housing 201 and the hand-held device 205 is a light pipe or light guide 203. Such light guides or light pipes are commercially available, and are generally of either the fibre-optic type or the liquid filled pipe type. In this arrangement, the handpiece 205 can be very small, comparable in size to a pencil. There are no heat problems associated with the handpiece itself, since it is acting as simply a conduit for the light which is generated at an external point. Of course, the output of the source within housing 201 is, in this embodiment, adjusted to take into account any attenuation of the light as it is transmitted through the pipe 203 to the handpiece. Also, wavelength band pass characteristics between 320 nm and 380 nm must be taken into consideration in optimizing a particular light guide design. The liquid filled light guides can be made to be wavelength or band pass selective, which eliminates the need for the visible light filter 128, as shown in Fig. 5. Appropriate changes in the power supply voltage and other circuit parameters are a matter of design choice, and within the state of the art.

WHAT WE CLAIM IS:—

1. An unconfined arc lamp filled with substantially only xenon, comprising main arc electrodes having spaced therebetween trigger electrodes for initiating and positioning a pulsed arc between said main arc electrodes, said electrodes being contained within a lamp envelope so that the pulsed arc forms freely between the electrodes without being confined by the walls of the said envelope, wherein at least a portion of said envelope is transparent to the ultraviolet radiation produced by the pulsed arc in the range of from 320 to 400 nanometers and the lamp envelope is filled with xenon at a pressure in the range of from in excess of 3 atmospheres up to 10 atmospheres, and wherein means are provided for delivering to the trigger electrodes trigger pulses at a pulse repetition rate of from 20 to 400 pulses per second.

2. A lamp as claimed in any preceding claim, wherein the envelope contains a glass window having glass which cuts off light wavelengths shorter than 320 nanometers.

3. A lamp as claimed in claim 2, wherein the pulse repetition rate is at least 100 pulses per second.

4. A lamp as claimed in claim 3, wherein the trigger pulses have a rise time of less than 2 microseconds.

5. A lamp as claimed in any preceding claim, wherein the lamp has a colour temperature in excess of 20,000°K.

6. A lamp as claimed in any preceding claim further comprising a visible light filter for reducing the visible light output of the apparatus.

7. A lamp as claimed in any preceding claim, wherein the main electrodes are supplied from a power supply means providing a stabilized output such that the ultraviolet radiation output of the lamp is substantially unchanged for power line voltage variations of from about −30% to +15%.

8. A lamp as claimed in any preceding claim, wherein the envelope is contained in a housing suitable for hand-held operation.

9 A lamp as claimed in claim 8, comprising a power supply for delivering electrical power to the main arc electrodes and trigger pulse circuitry for delivering trigger pulses to the trigger electrodes, the power supply and trigger pulse circuitry being contained in a second housing outside of the first men-

tioned housing and coaxial connecting means between the second housing and the first housing for delivery of the said electrical power and trigger pulses.

10. A lamp as claimed in claim 8 or 9, wherein means are provided for directing the ultraviolet light at a restricted surface area.

11. A lamp as claimed in any one of claims 1 to 7, comprising:

[a] an external housing for containing said envelope;

[b] hand-held means for directing ultraviolet light at a restricted surface area; and

[c] light guide means for transmitting the ultraviolet radiation from the external housing to the hand-held means.

12. A lamp as claimed in claim 11, wherein the light guide means is a quartz rod having a reflective coating covering at least a portion thereof.

13. An arc lamp substantially as herein described with reference to any one of the embodiments shown in the accompanying drawings.

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1979
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

Fig. 1

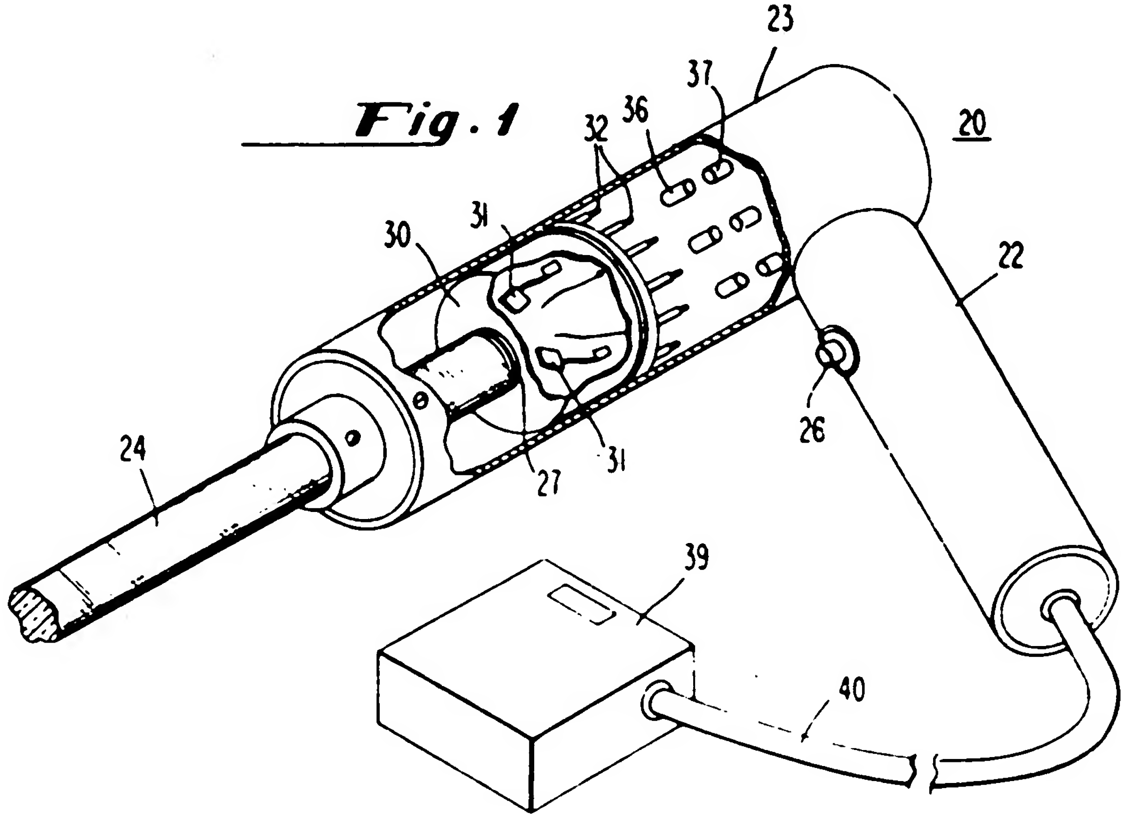
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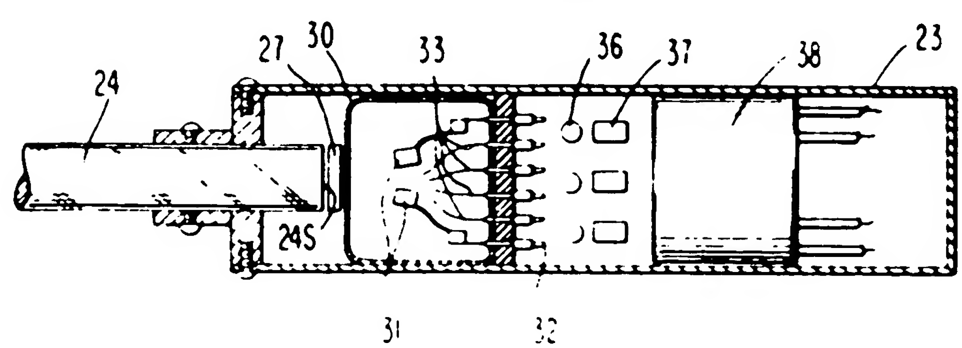
Fig. 2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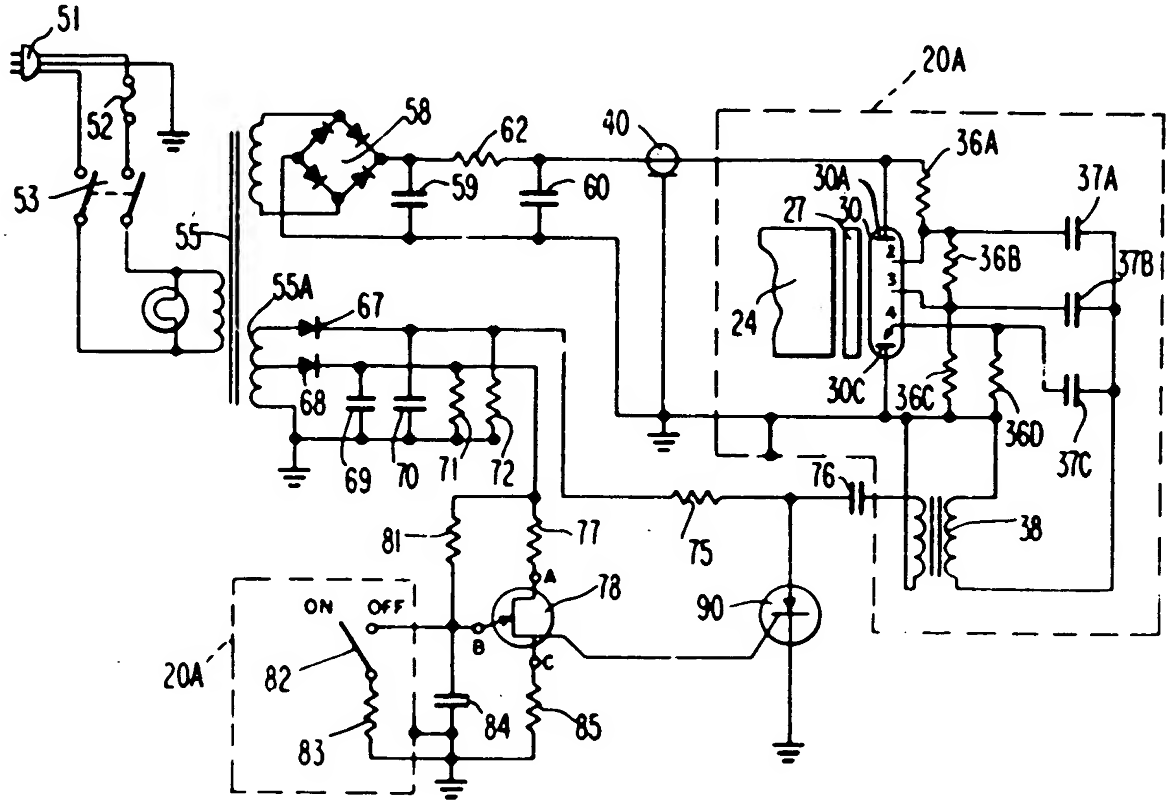
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68
30C
36C
36D
37C
69
70
71
72
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C
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Fig. 4

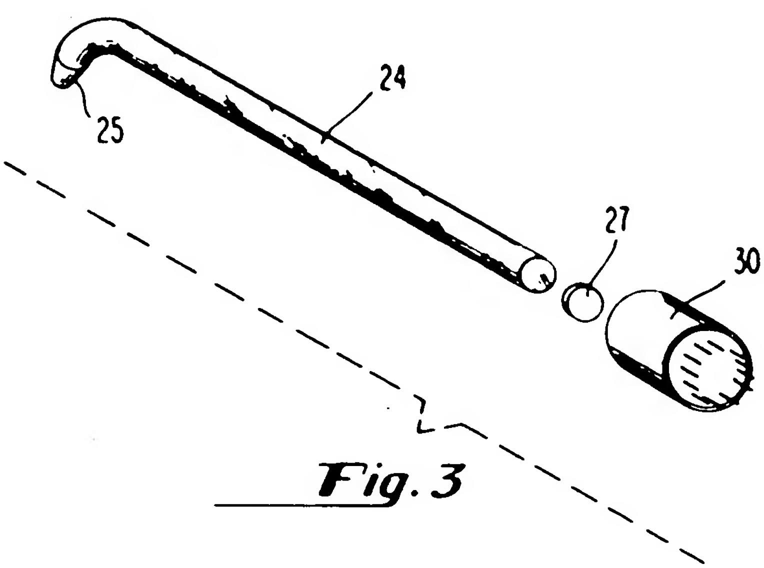
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Fig. 3

1 548 997 COMPLETE SPECIFICATION

3 SHEETS This drawing is a reproduction of the Original on a reduced scale.

SHEET 3

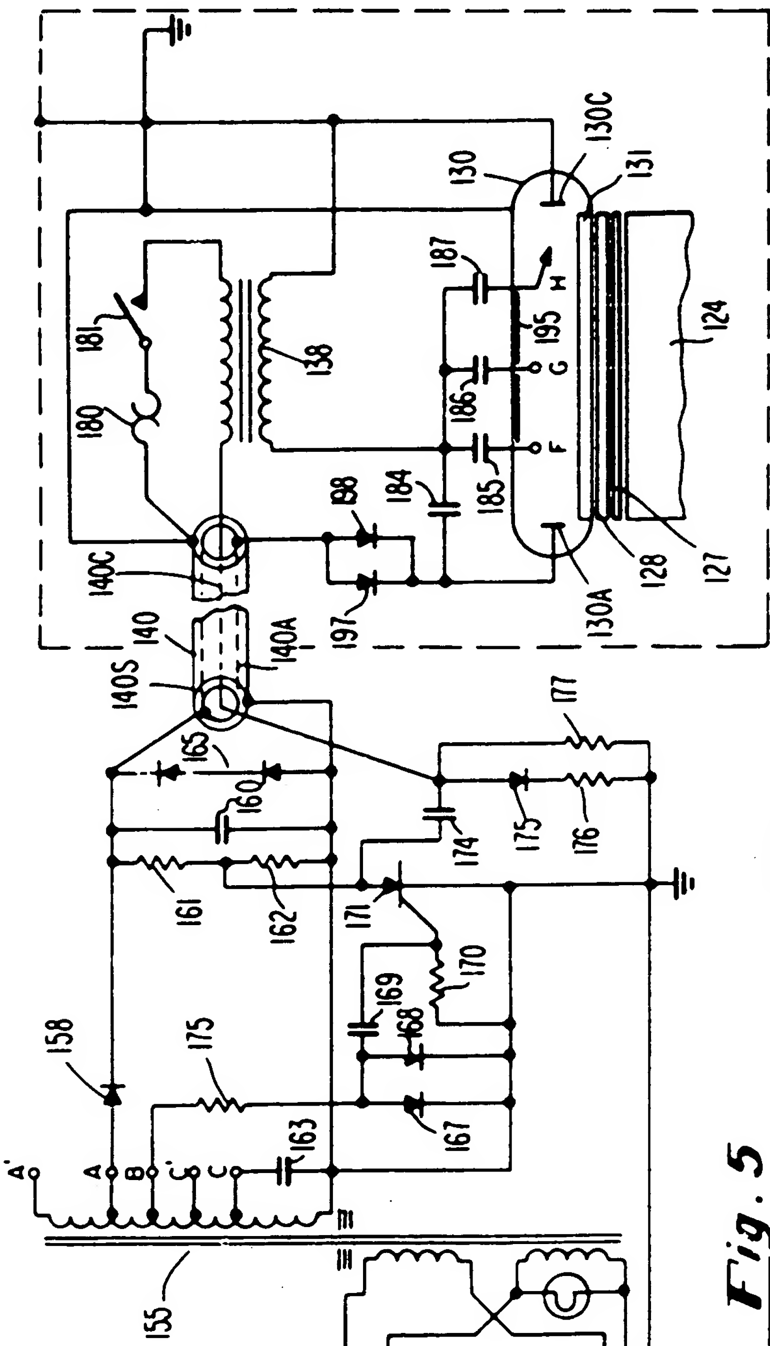

Fig. 5

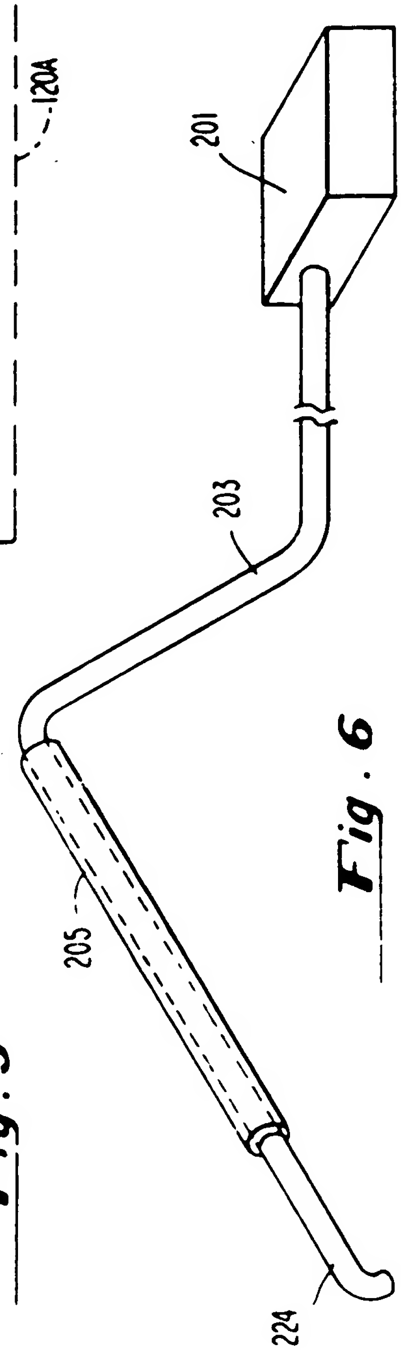

Fig. 6